Submitted: 27 August, 2021 Accepted: 22 October, 2021 Published: 08 May, 2022 DOI:10.22514/sv.2021.241

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COMMENTARY

Point-of-care testing as the future of pre-hospital emergency medicine: an overview

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Abstract

Point-of-care testing (POCT) plays an increasingly important role in pre-emergency medicine by ensuring that patient's continuum of care is commenced before arrival at health facilities. Given the benefits of POCT during the COVID-19 pandemic, this commentary described the advantages and disadvantages of POCT, and its current practices in pre-hospital emergency medicine. Point-of-care tests are easy to operate, cost-effective, and yield quick and accurate response, but are posed with challenges such as safety errors, poor adherence to quality control standards, and inspection errors. To optimize the benefits of POCT in pre-emergency medicine, it is required that regular trainings are conducted for POCT operators, and total compliance to POCT handling and management guidelines should be considered by each POCT operator.

Keywords

COVID-19; Emergency care; Emergency medicine; Point-of-care testing; Laboratory tests

1. Introduction

Laboratory tests are one of the most important indicators of a patient's condition and diagnosis. Classic laboratory tests refer to the collection of biological specimens, such as blood samples, and the transfer of such to a hospital laboratory or other laboratory facilities for histological analysis [1]. Classic laboratory tests are time-consuming because they require complex procedures. The lag in conducting these procedures can have dramatic consequences on patients' health especially during emergencies. Point-of-care testing (POCT), which is very suitable during emergencies, is a paradigm shift evolving to replace classic laboratory tests. POCT enables the healthcare team to obtain objective information about a patient at his/her bedside. Point-of-care tests are usually performed by clinical staff with minimal or no laboratory training, as obtainable in syndromic management of infectious diseases. Thus, POCT enables prompt diagnosis, improved turnout time for laboratory results, rapid assessment of improvements/deterioration in patients' condition, early commencement of treatment/management options, and adjustment of an appropriate treatment to meet patients' needs [1]. A qualitative study among clinical staff of emergency departments in rural and remote North South Wales, Australia found that POCT services enhanced patients' outcome because it provided the opportunity for effective and efficient management of patients.

POCT is an established standard in emergency medicine. Currently, the rapid test for β-HCG is urine. POCT measurement of lactate, blood gases, cardiac tropinin, haemoglobin, and hematocrit are well established in preclinical emergency medicine [2]. Furthermore, there are many settings for its applications. These include ambulatory care for monitoring heart failure [3], pediatric care [4], and management of sexually transmitted infections [5]. In a world where global, natural, and human-made disasters occur frequently, modern technological tools may help to develop plug-and-play diagnostics [6]. In fact, there is a paradigm shift towards the adoption of smart devices in telemedicine, which could serve as a gateway for the next generation of POCT technologies in healthcare monitoring and management. COVID-19 public health interventions are focused on breaking the chain of

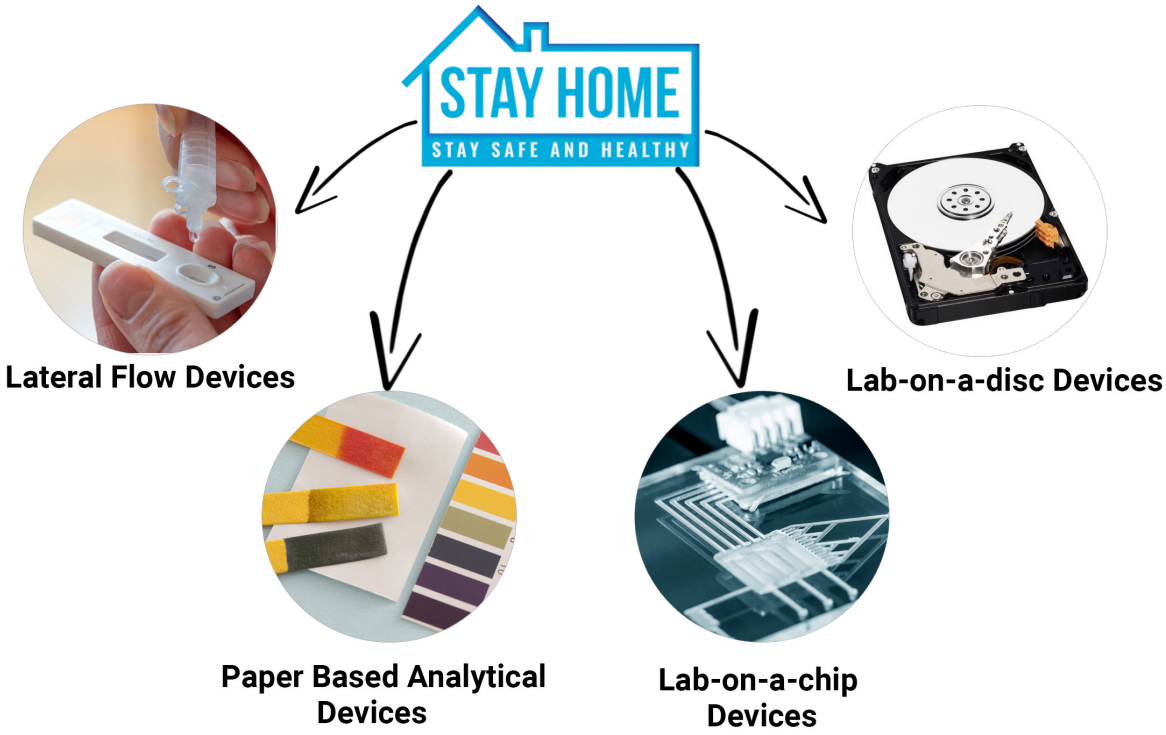

FIGURE 1. Point of care testing devices in resource-limited settings [14].

COVID-19 transmission and help to dentify infected persons before infectivity begins [7]. Adequate monitoring of patients through POCT gained wide acceptance during the COVID-19 pandemic [8]. This was primarily due to the lack of any known vaccine between the first two waves (March–June, and July–January), the high mortality rate, and the need for regular monitoring of patients' health [9, 10].

Given the benefits of POCT in emergency medicine especially during the COVID-19 pandemic, this commentary aimed to describe the advantages and disadvantages of POCT, and its current practices in pre-hospital emergency medicine.

2. Discussion

POCT technologies are composed of automated high-thoroughput instruments used to conduct nearly 1000 tests daily [11]. These technologies subject biological samples to nucleic acid extraction and amplification, the results of which are interfaced with the laboratory information system [11]. Many automated instruments with similar testing capacities and workflow benefits that depend on Nucleic Acid Amplification Tests technologies are now available. These instruments include the Hologic Panther SARS-CoV-2 assay (Hologic, USA), Abbott RealTime SARS-CoV-2 assay (Abbott Molecular, USA), the NeuMoDx SARS-CoV-2 assay (NeuMoDx Molecular, USA), and BD Max reagents (Becton, Dickinson, USA) [12]. Much progress has also been made regarding the use of semiautomated robotics for nucleic acid extraction, specimen processing, RT-PCR amplification, and interfacing for reporting of data. Nowadays, as evidence-based medicine advances in critical pre-hospital care and medical transport, proper use of POCT tools can improve patient care and lower overall healthcare costs. Thus, the global POCT market is projected to reach US$36.96 billion in 2021 from US$23.16 billion in 2016. POCT helps to avoid some indirect healthcare costs and allows timely availability of cardiac troponins particularly in remote settings [13]. Australia accounts for the country with the largest managed POCT services, with more than 5000 operators on almost 300 POCT devices in nearly 150 rural and remote emergency departments, most of whom have unreliable power supply [14] (Fig. 1, [14]). In the pre-hospital troponin *T* testing in the diagnosis and triage of patients with suspected acute myocardial infarction in Denmark, the pre-hopsital test identified nearly half of the patients who were confirmed to have acute myocardial infarction at the initial hospital test [15]. This array of findings suggests that a high success rate is associated with POCT in pre-hospital testing.

Despite the benefits of POCT, the modern technique is yet faced with some challenges, including safety errors, poor adherence to quality control standards, and inspection errors. The assays employed in POCT techniques are less sensitive and more susceptible to interference compared to those performed in the clinical laboratory [13]. For instance, POCT glucose methods are often used to measure glucose levels that are not specific to glucose alone but could be interfered with by other sugar compounds e.g., maltose and galactose. Due to the inaccuracy and lack of specificity of these tests, POCT glucose measurement is yet to be endorsed for the diagnosis of diabetes [13]. In addition, point-of-care test for measuring cardiac troponin lacks analytical sensitivity compared to that conducted in traditional laboratories. As obtained with laboratory tests, point-of-care tests are susceptible to errors. In a study conducted by Cantero and colleagues, it was found that pre-analytical erros were more common with POCT compared with central laboratory testing [16]. The

pre-analytical errors were specifically found to be associated with patients' identification; operators failed to confirm the identities of two patients in nearly half of point-of-care tests performed. Pre-analytical errors with POCT (45%) far exceeds errors in clinical laboratory tests (0.02%) [16]. If clinical management decisions are made on receipt of an erroneous POCT result, patients could be exposed to huge health risks [17].

A study conducted by O'Kane *et al*. [17] in one nonacute and two acute hospital sites in Northern Ireland reveals that the most common error attributed to POCT was due to the absence of a certified operator to conduct the test. The operator's inability to maintain POCT instrument could result to a delay in analysis; a frequent error associated with POCT blood gas analysis. Due to the limited human resources available and a lack of knowledge regarding quality management for POCT, compliance with accreditation standards could be challenging [18].

2.1 i-STAT

2.1.1 Advantages

The i-STAT is a device that has the most comprehensive test; the CHEM8+ cartridge that measures electrolytes (Na^+, K^+, Cl^-, Ca^{2+}), $CO_2{}^-$, anion gap, glucose, creatinine, urea nitrogen, hematocrit, and hemoglobin. All i-STAT cartridges that measure arterial blood gases, troponin, or lactate, are tests of moderate complexity [13].

2.1.2 Disadvantages

i-STAT cartridges must be refrigerated before use and then warmed to room temperature.

2.2 Epoc blood analyzer

2.2.1 Advantages

The epoc blood analyzer is equipped with test cards that contain the wireless card reader and sensors. The test cards, which do not require cooling, use selective electrode potentiometry to measure the levels of arterial blood gases, electrolytes, glucose, hematocrit, hemoglobin, and lactate. Due to its cost-effective nature, the epoc blood analyzer is being marketed as an alternative to i-STAT [15, 19].

2.2.2 Disadvantages

The epoc blood analyzer is moderately a complex test. Failure rates of the blood analyzing system include: (a) card failures, in which assays can not be performed due to a breakdown of the test cards; and (b) internal quality control errors, in which internal quality control set-up is not permeable to single or multiple analytes [19].

2.3 Quick manual test

2.3.1 Advantages

Newer devices are also being introduced to the market, an example of which is the quick manual test for bacterial infections invented by the team of scientists at McMaster University, which can provide accurate, reliable results in less than an hour and immediately on site. Currently, the test is used to diagnose urinary tract infections from real clinical samples, but the team is working on adapting it to detect other forms of bacteria as well. The general population across the globe count on healthcare workers to adapt the quick manual test for the rapid diagnosis of viruses, including SARS-CoV-2. The new DNA-based technology uses a portable device the size of a USB flash drive with a microchip that can analyze drops of body fluids such as blood, urine or saliva with molecules detecting the infection's specific protein signature. The device then connects to a smartphone which displays the results. The absence of environmental limitation to quick manual test makes this test suitable for use across multiple settings.

2.3.2 Disadvantages

Quick manual tests yield test results with less accuracy compared to other POCT methods. Quick manual tests are impractical in comparing large data compared, but batch testing helps to overcome this challenge. As a result, repetitive tests, and these consume both time and resources.

2.4 Lactate tests

2.4.1 Advantages

The use of lactate levels is increasingly becoming the standard of medical care. Lactic acid production is indicative of anaerobic metabolism, so any condition that results in anaerobic metabolism will lead to an increase in lactic acid levels. Normal lactate levels are less than 2 mmol/L, and levels >4 mmol/L are generally considered important to query the presence of any underlying disease. Lactates are formed as a product of anaerobic metabolism and are thus markers of developing/galloping shock. Lactates allow early detection of developing shock (much faster than sometimes "deceptive" vital signs). There are many patients whose hypovolemic hemorrhagic shock will be much different than as described in print. For example, patients treated with beta-blockers reported reduced compensatory response. For patients with retroperitoneal bleeding—lack of a hard/plank abdomen), elevated lactate levels can be resourceful. The later the tranexamic acid is administered, the lesser its effectiveness and the greater the need for transfusion/higher mortality. Lactates support the diagnosis of septic patients or in making correct and valuable ATMIST protocol (possibility of proper preparation of the team for the patient's arrival or sending it to the appropriate reference unit dealing with injuries as well as ordering blood and booking the operating room).

2.4.2 Disadvantages

Caution should be exercised when considering the interpretation of lactic acid levels because it may not be relevant if it is not correlated with the patient's condition. Elevated lactate levels are not normal, but do not always indicate a serious medical condition. After undergoing stressful physical conditions during exercise, athletes have increased lactate levels because their muscles have been heavily strained. Understanding the importance of elevated lactate levels also requires knowing when to look out for it [20].

2.5 D-dimer testing

2.5.1 Advantages

It has been suggested that point-of-care D-dimer testing could be useful to reduce turnaround time (time to results), and time to diagnosis, discharge or referral in patients affected by venous thromboembolism, in overcrowed emergency departments. They also have sufficient diagnostic sensitivity to rule out acute venous thromboembolism if combined with other standardized clinical management techniques [21].

2.5.2 Disadvantages

Positive D-dimer test results are not sufficient confirmatory tests. This therefore implies that D-dimer tests need to be always coupled with other tests to determine diagnostic accuracy.

3. Current practices on POCT in pre-hospital emergency medicine

In the study conducted by Venturini and colleagues, it was found that there was no significant difference between POCT devices operated in a moving ambulance and the measurement of cardiac troponin I levels obtained by POCT devices in the emergency department [22]. This confirms the practicality and utility of POCT in prehospital emergency contexts especially in future events of pre-hospital myocardial infarction. To examine the feasibility of pre-hospital physician assessment of hemostatic parameters, Beynon *et al*. [23] in an observational study confirmed that POCT results are more efficient than results received from the central laboratory. In the reference study, point-of-care international normalized ratio testing conducted on 103 patients revealed a pre-hospital sensitivity of 100% as well as a specificity of 98.7% for the detection of coagulopathy [23]. Furthermore, a median time gain of 69 minutes (ranging between 33 to 336 minutes) was achieved through POCT, and this was highly advantageous for patients with intracranial hemorrhage [23]. Thus, POCT in the pre-hospital setting is reliable, valid, and helpful to clinical care. POCT provides an opportunity to commence care prior to patients' arrival at a receiving health facility, thus allowing for mobilization of resources to provide care on arrival in a timely manner. Early assessment of international normalized ratio in patients is proven to aid decisionmaking on patients' transfers as well as pre-hospital triage to reduce mortality and improve survival rates [24]. Findings from the CRASH-2 trial specified that prehospital administration of antifibrinolytic drug tranexamic acid reduces death rates in bleeding trauma victims [25]. POCT devices thus play a positive role in optimizing paients' health and enhancing test outcomes [26].

4. Conclusions

POCT plays an increasingly important role in pre-emergency medicine by providing an opportunity to commence care prior to patients' arrival at health facilities, thereby improving patients' chances of survival. Despite these benefits, POCT is posed with some challenges, namely: safety errors, poor adherence to quality control standards, and inspection errors. To optimize the benefits of POCT in pre-emergency medicine, it is required that quality errors and inspection errors are avoided by operators of POCT devices. Regular trainings need to be organized for operators of POCT devices, and total compliance to POCT handling and management guidelines should be considered by each device operator. Longitudinal research needs to be conducted to characterize the limitations of specific POCT devices in pre-hospital emergency care.

AUTHOR CONTRIBUTIONS

Draft preparation—LS, MP. Writing, editing—FC, AAA, OSI, GN. Literature search—FC, AAA. All the authors approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest. Francesco CHIRICO and Lukasz SZARPAK are serving as the Editorial Board members of this journal. We declare that Francesco CHIRICO and Lukasz SZARPAK had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to YZ.

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How to cite this article: Lukasz SZARPAK, Gabriella NUCERA, Michal PRUC, Olayinka Stephen ILESANMI, Aanuoluwapo Adeyimika AFOLABI, Francesco CHIRICO. Point-of-care testing as the future of pre-hospital emergency medicine: an overview. Signa Vitae. 2022; 18(3): 153-157. doi:10.22514/sv.2021.241.